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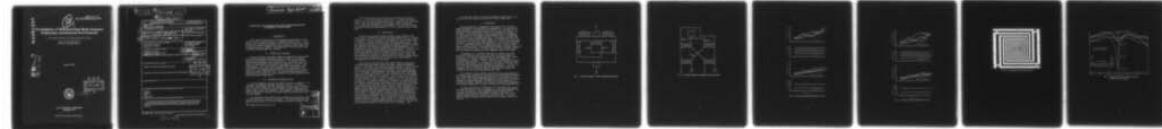
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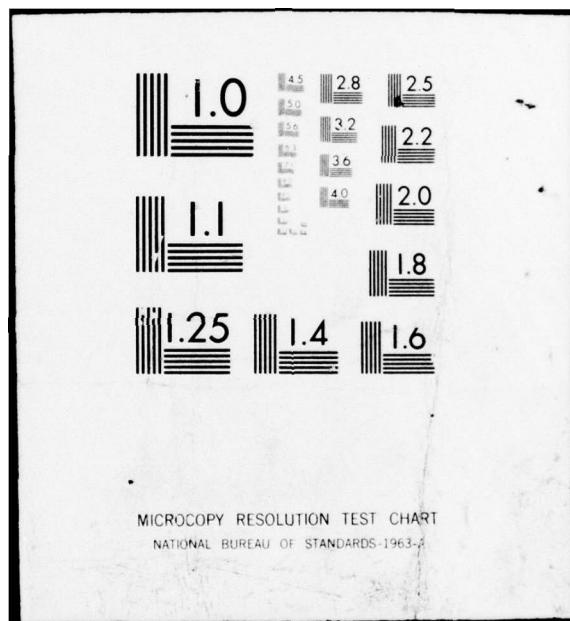
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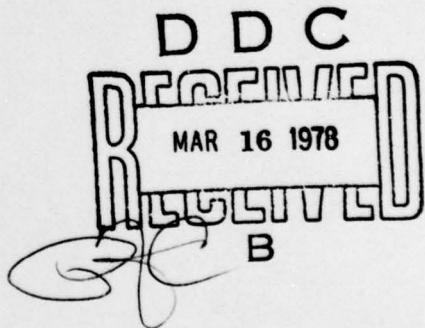
Investigation of Wideband Dual Mode Antennas Employing a Symmetrical Feed Network

R. E. NEIDERT, B. SHELEG, H. E. HEDDINGS and B. D. WRIGHT

*Microwave Techniques Branch
Electronics Technology Division*

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INVESTIGATION OF WIDEBAND DUAL MODE ANTENNAS EMPLOYING A SYMMETRICAL FEED NETWORK

I. INTRODUCTION

Field reports indicated that the shipboard antenna which is the subject of this report performed its intended function poorly. It was deduced that the antenna radiation patterns were unsuitable as a result of the feed network irregularities (e.g., asymmetry) and perhaps from interactions with its radome. The antenna was a four arm spiral with a Sum-and Difference-Mode feed network.

II. INVESTIGATION APPROACH

The Naval Research Laboratory proposed a symmetrical feed network which would theoretically guarantee phase tracking of the signals feeding opposite arms of the four arm spiral. The original network theoretically guaranteed phase imbalance, to the extent to which the ripple in asymmetrically incorporated Schiffman phase shifters could be maintained. Also, NRL decided to investigate two shapes for the spiral antenna--one curved and conforming to the radome shape, the other flat. The original antenna was flat and incorporated a low dielectric constant "focusing" lens. The lens had been experimentally determined to be beneficial for the particular antenna employed but was poorly understood theoretically.

III. ANTENNA/FEED NETWORK DESIGN

A block diagram of the NRL feed network is shown in Figure 1. For reference, the original network is shown in Figure 2. In Figure 1 the paths, particularly from the Difference (Δ) Mode input, to antenna ports 1 and 3 are identical; also the paths from the Δ -Mode input to antenna ports 2 and 4 are identical. This symmetry to opposite spiral arms was designed to minimize the Δ -Mode radiation pattern null shift versus frequency.

The symmetrical feed networks were designed and constructed using standard three-layer stripline techniques. The measured amplitude and phase characteristics of two feed networks are shown in Figures 3 and 4.

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The four-arm spiral used for the curved antenna is pictured in Figure 5. It is a log periodic design with $\tau = 1.106807$ vertically, and with the horizontal dimensions adjusted to make the flat projection square. NRL also constructed a flat, square, spiral design with $\tau = 1.106807$ both vertically and horizontally. The projected antenna physical aperture was approximately 8.9 cm (3.5 inches) square in both cases.

IV. TEST RESULTS

The NRL curved antenna produced normally shaped patterns when tested alone, yielding null stability of approximately +17 to -7 degrees in azimuth and +13 to 0 degrees in elevation, over the frequency band of interest. (In these and later null stability figures, "plus" is to the Right for azimuth direction and Up for elevation direction.) When this antenna was placed in its mounting environment and when the radome was installed, the patterns deteriorated to unrecognizability, becoming more or less omni-directional with large ripples, and with little distinction between Sum and Difference mode excitation. It was observed experimentally that the patterns improved if the antenna face were dropped back one-half to one-inch from the radome. Since this repositioning was physically impossible with the curved antenna design, the flat design was tried since the center of its face falls at approximately one-inch from the radome.

Final tests on the flat-faced NRL spiral antenna, installed in its operational environment inside the radome, produced reasonable results. Null depth, for elevation direction between 0° and 3° , varied from 8 to 34 dB with the null falling between -14 and +9 degrees in azimuth, over the frequency band of interest. The original antenna, not of NRL design, incorporating a flat faced spiral and a "matching" lens, was tested under exactly the same conditions as the NRL antenna, operationally installed in the radome. Its null depth, for elevation direction between 0° and 3° , varied from 10 dB to 35 dB with the null falling between +14 and -7 degrees in azimuth, over the frequency band of interest. The original antenna also averaged 5 dB higher than the NRL design in absolute gain, on boresight, for the Sum mode excitation. It is believed that the lower gain of the NRL design, except for that portion which arises from the modest increase in the feed network losses, could be improved by reducing the back cavity loading; however, after observing that the radiation patterns were not significantly better than the original design, further effort on increasing gain is not justified. Incidentally, the radiation patterns of the NRL flat spiral design were degraded when a lens similar to that used on the original antenna was tried. Since the NRL spiral design is somewhat different from the original antenna spiral, it is not surprising that the lens effect is quite different for the two antennas. The NRL flat spiral antenna described in this report does not employ a lens.

Full pattern results on both working antenna designs will be retained at NRL, with copies provided on a "Need to Know" basis.

V. CONCLUSIONS

The development of a symmetrical feed network for a dual mode spiral antenna has been successfully demonstrated. The resultant antenna performance, utilizing this feed network, has been shown to be adequate for the intended application in an anechoic environment. It is useful to have the results of this design approach in evaluating the performance of the original antenna design, since it strengthens the validity of the following conclusion. The original antenna, when tested in an anechoic environment, appears to perform about as well as an antenna of its type can. There appear to be too many uncontrollable variables to achieve significant improvement. Some of these variables are: 1) Random VSWR effects, 2) Radome dielectric constant repeatability and anisotropy, 3) Fabrication and assembly tolerance variations (both in the circuits and in spatial factors), and 4) Possible interaction between the antenna and other components within the radome.

Furthermore, it is possible that even if a perfect dual mode spiral were developed, with zero null drift in either azimuth or elevation, the multi-path shipboard and sea environment could render it ineffective. Figure 6 shows the results of an experiment demonstrating this effect. Curves 1 and 2 give the Sum and Difference patterns, respectively, at a frequency in the band of interest, when the operational antenna system environment is anechoic. Curves 3 and 4 give the Sum and Difference patterns, respectively, at the same frequency, when a reflection plane has been simulated between the transmitter and the receiving antenna under test.

The difference mode radiation pattern from any spiral antenna of the general type discussed in this report has an approximately conical null on boresight with strong radiation at 15 to 60 degrees off the cone center. The strong radiation capability looking 15 to 60 degrees downward on azimuth boresight (relative to the weak capability on elevation boresight) provides for excellent reception and exaggeration of multipath reflections, in effect filling in or distorting the null.

It seems possible that utilization of a difference mode pattern yielding this type of null on boresight is a non-optimum approach for the field application. Other approaches being considered must recognize the multi-path environment existing in the field, and no design approach should be considered successful until it has been shown to produce accurate results under the full range of field conditions.

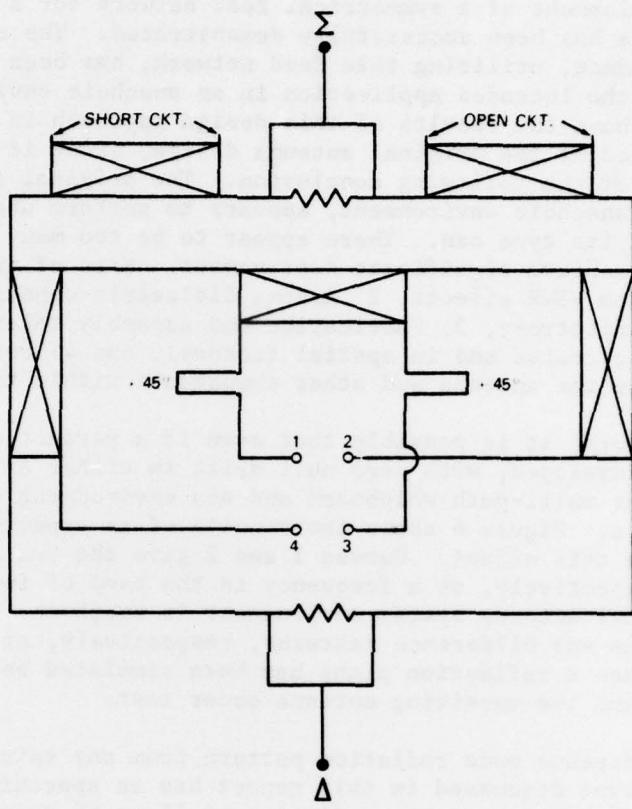


Fig. 1 — Schematic diagram of NRL symmetrical feed system

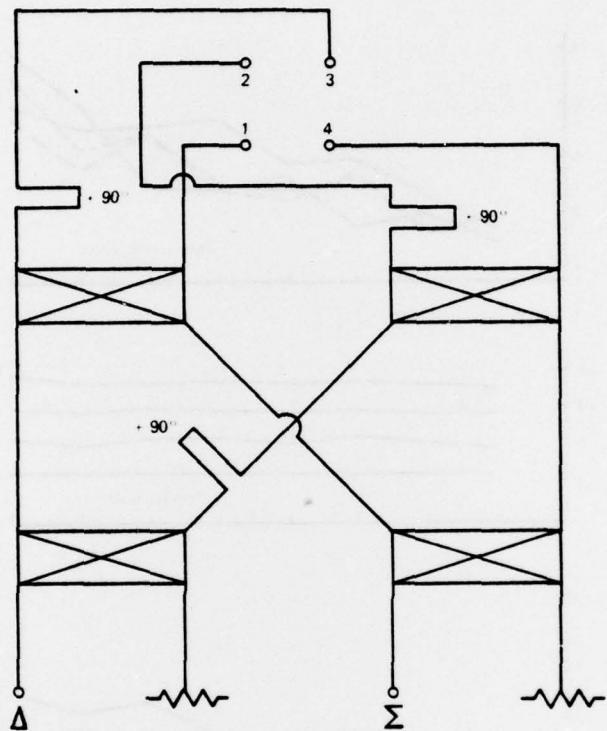


Fig. 2 — Schematic diagram of original antenna feed system

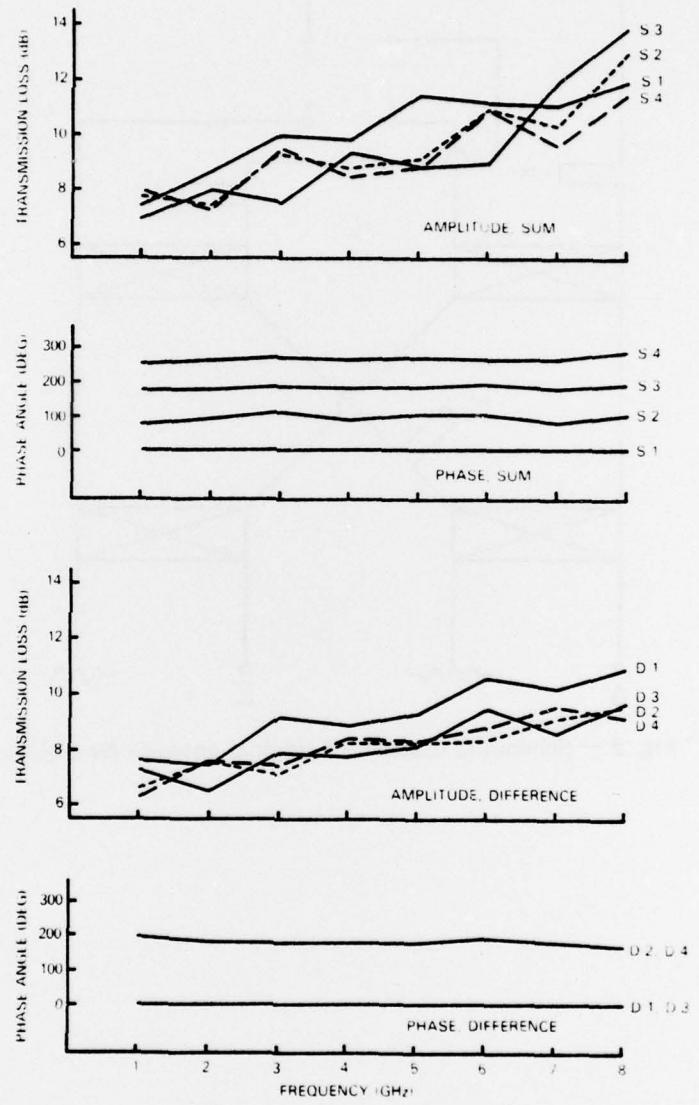


Fig. 3 — NRL feed network performance, unit #1

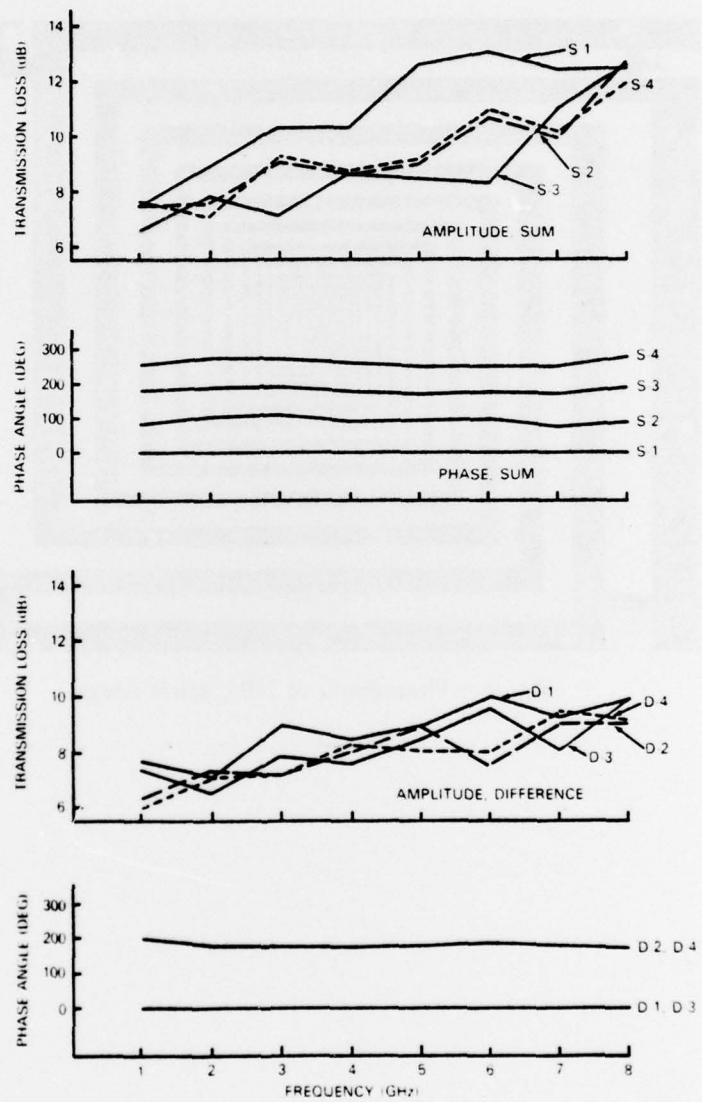


Fig. 4 — NRL feed network performance, unit #2

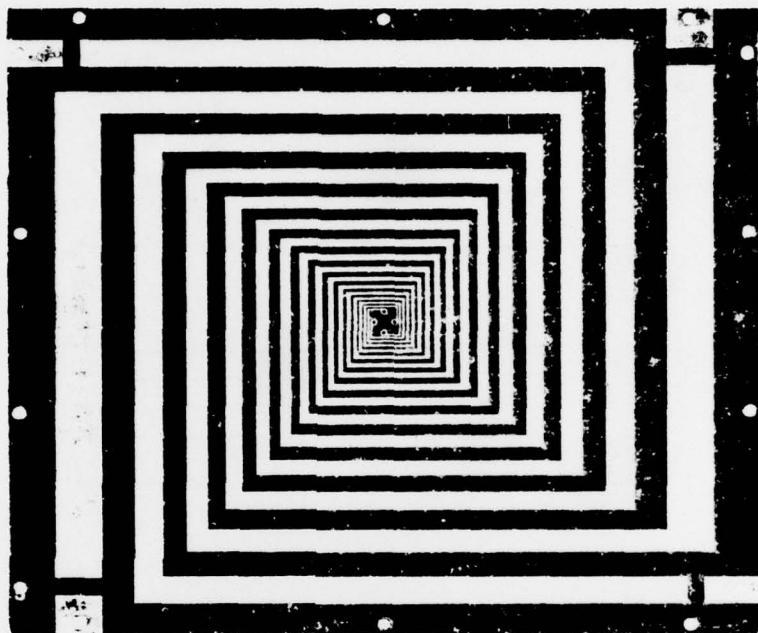


Fig. 5 — Photograph of NRL spiral design

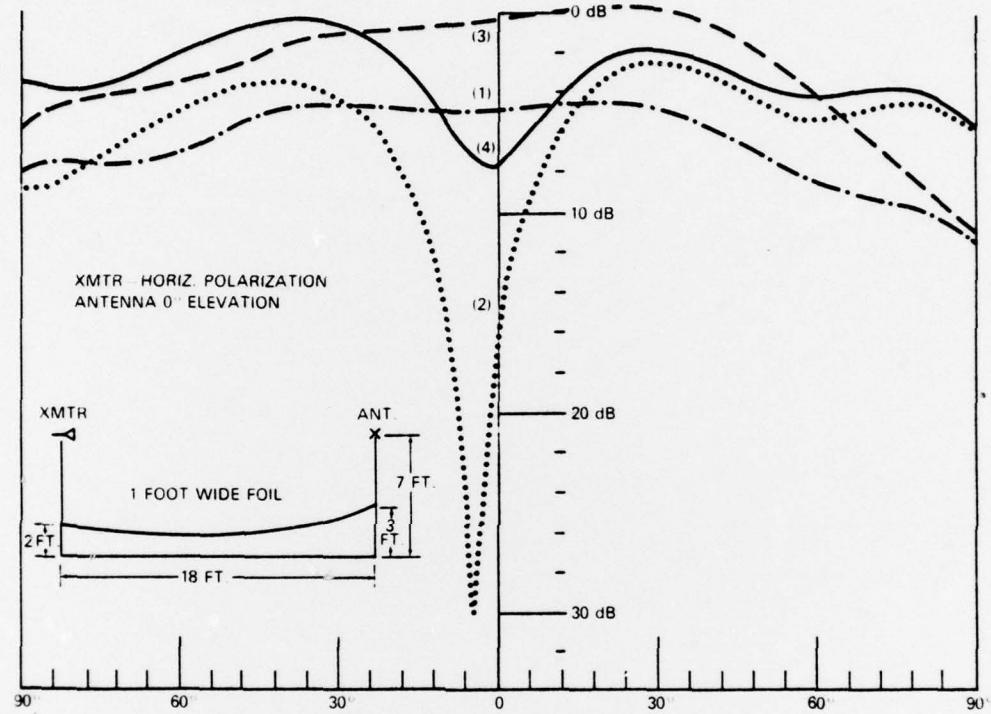


Fig. 6 — Simulated multipath effect on patterns
(original antenna in radome)

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